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EXPLANATION OF PLATE XVII.—Fig. 1. Typical fusiform spore.

Fig. 2. Typical clavate spore.

Fig. 3. Thick-walled clavate spore of the form found on very outside of the spore mass.

Fig. 4. Showing normal method of germination.

Fig. 5. Method of germination of spores in an excess of water.

Fig. 6. Method of germination of spores when damp.

Fig. 7. Simplified method of same.

Fig. 8. Fusiform spore germinating by the end.

Fig. 9. Clavate spore germinating in a similar manner.

Fig. 10. Terminal germination brought about by same conditions as in 6 and 7.

All these figures are magnified 410 diam. and then reduced one-third, except Fig. 5, which is magnified 250 diam.

Cryptogamic Laboratory of Harvard University.

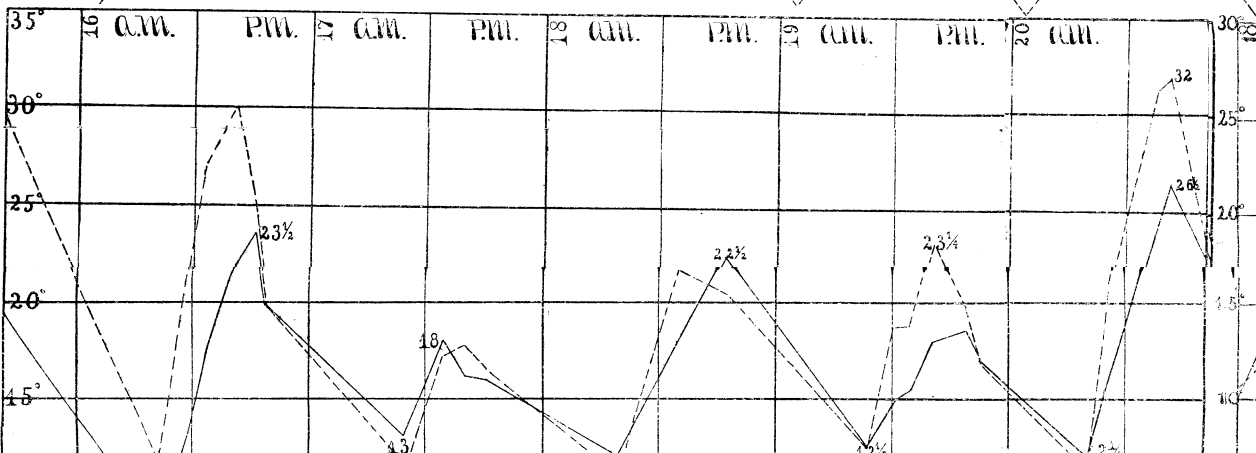
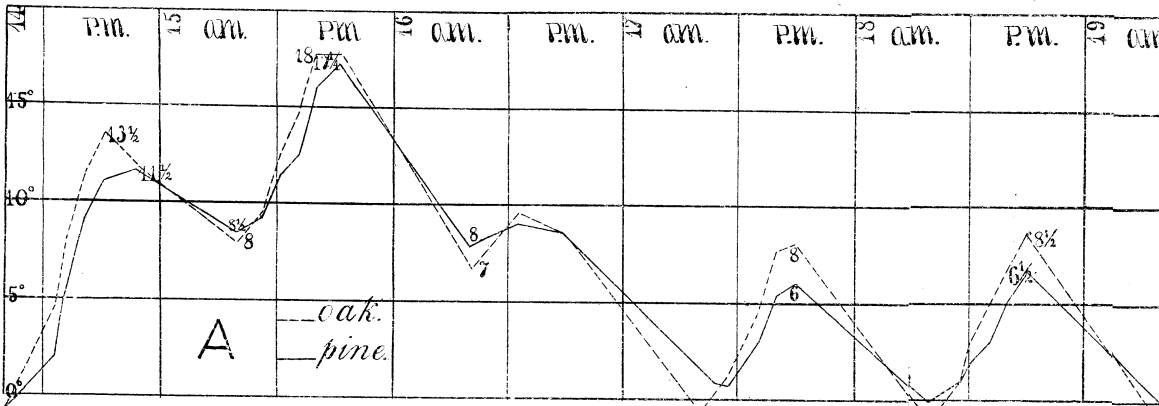
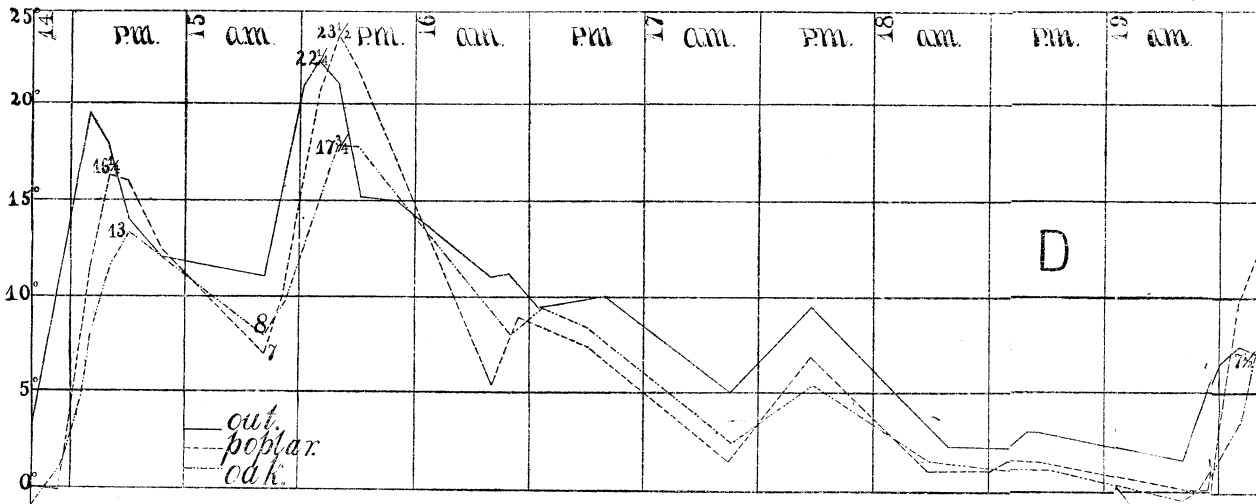
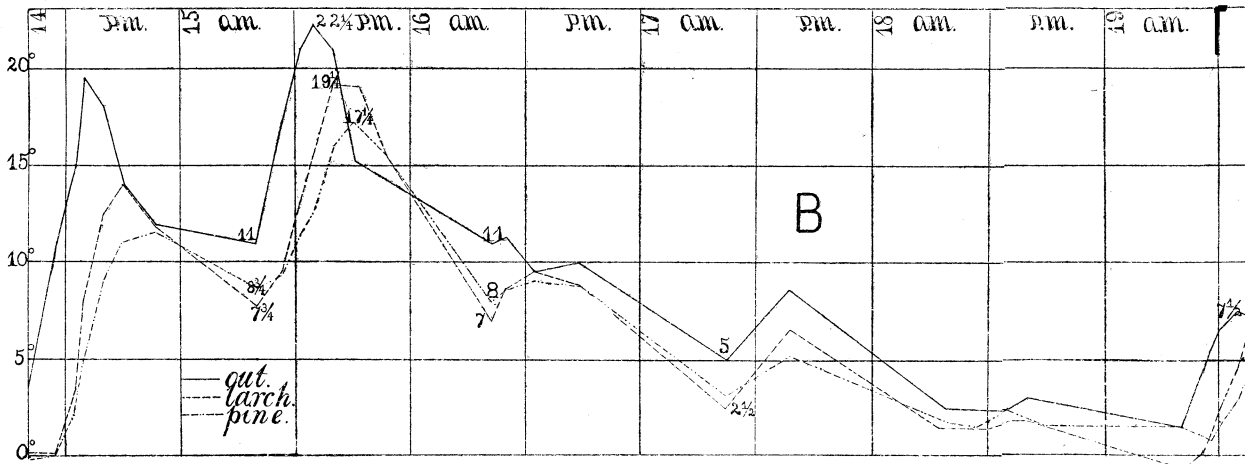
Observations on the temperature of trees.

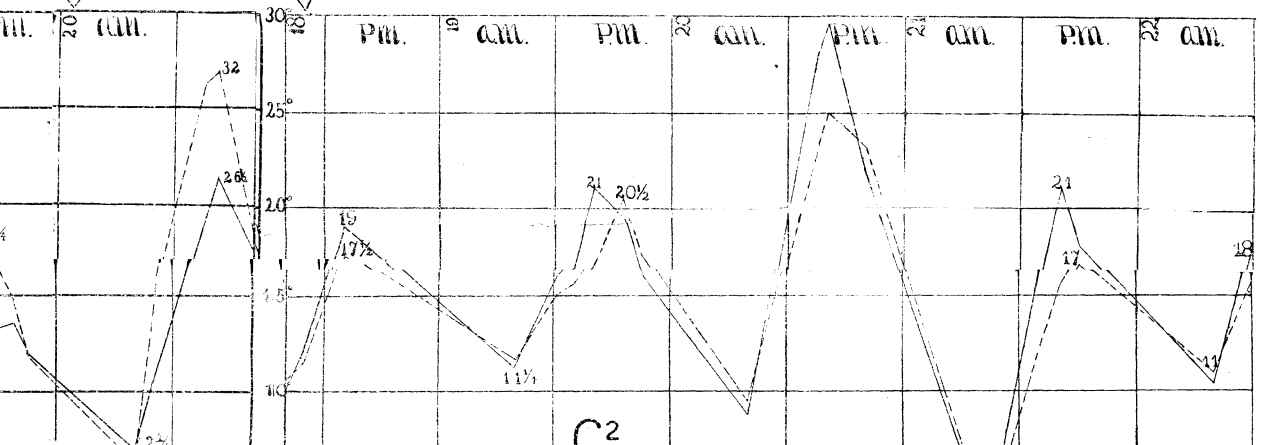
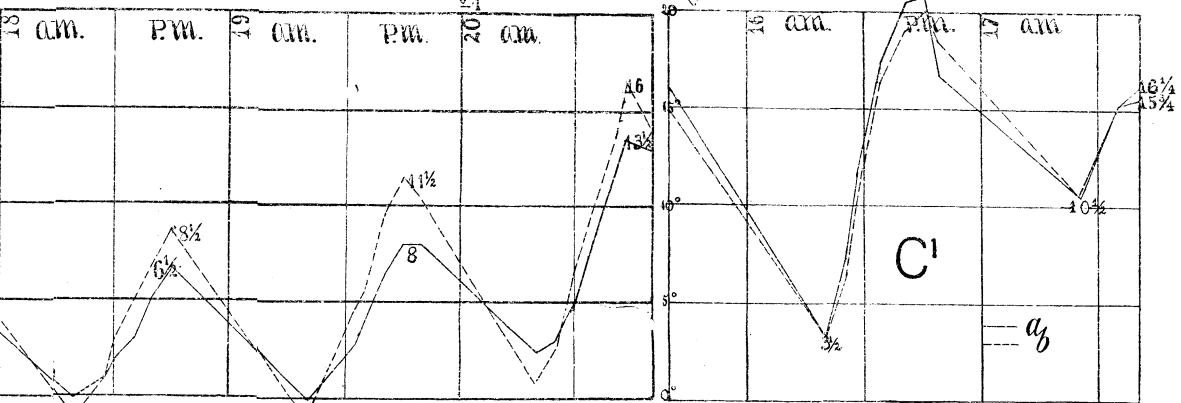
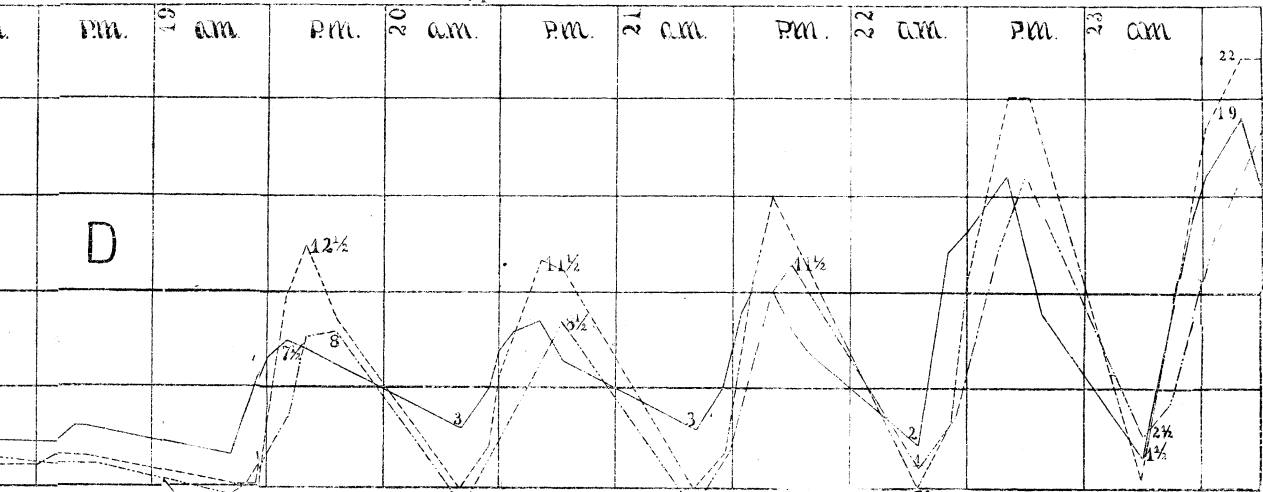
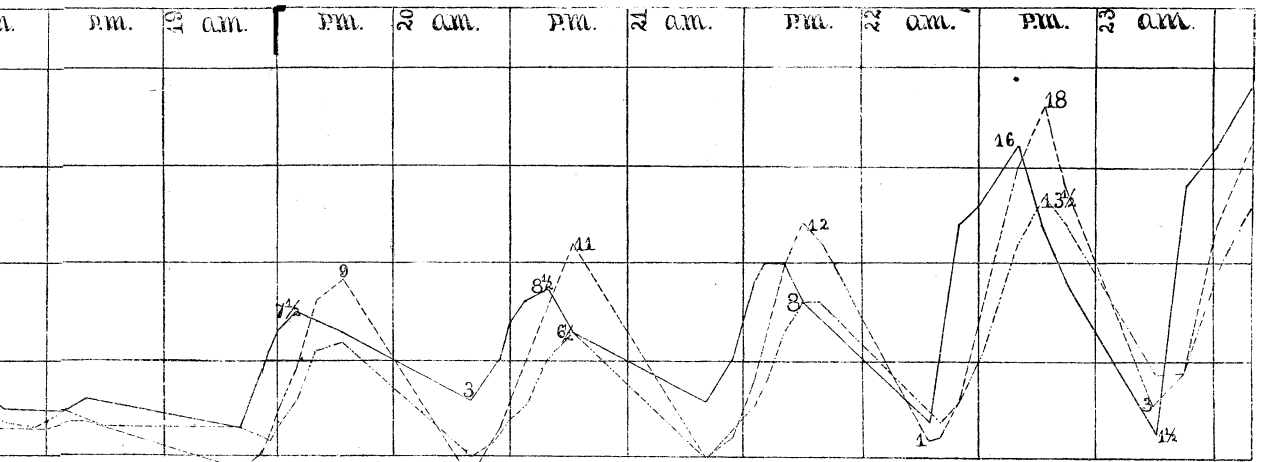
H. L. RUSSELL.

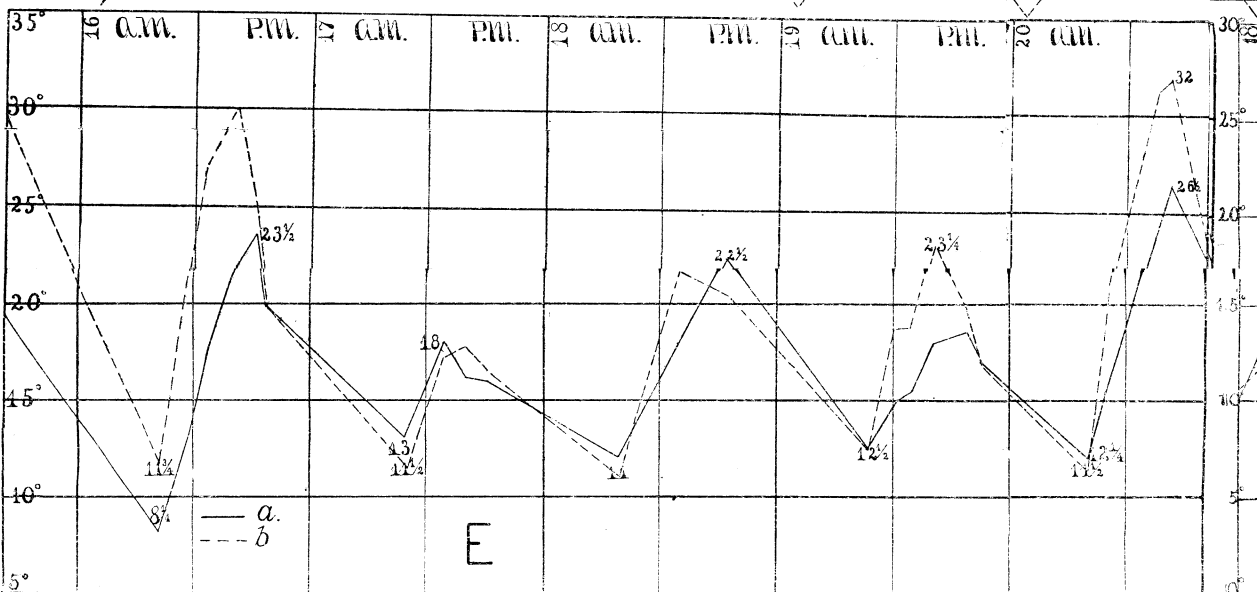
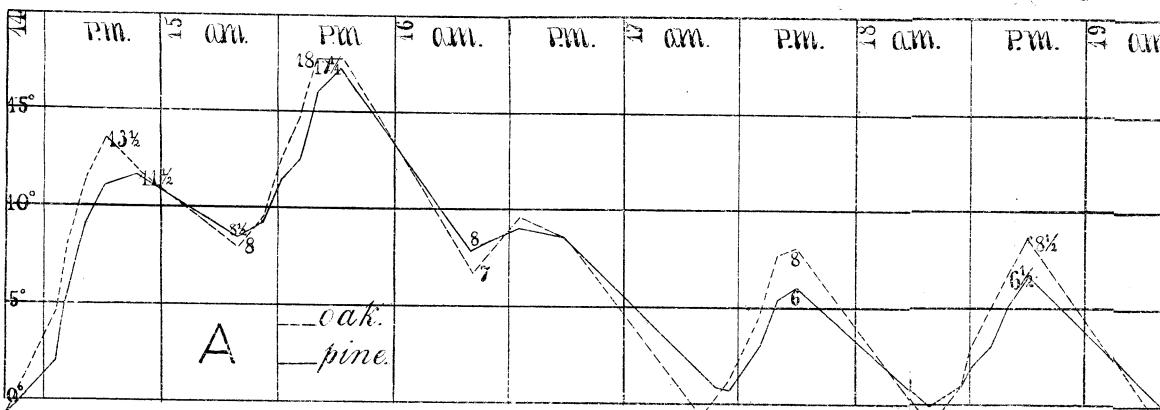
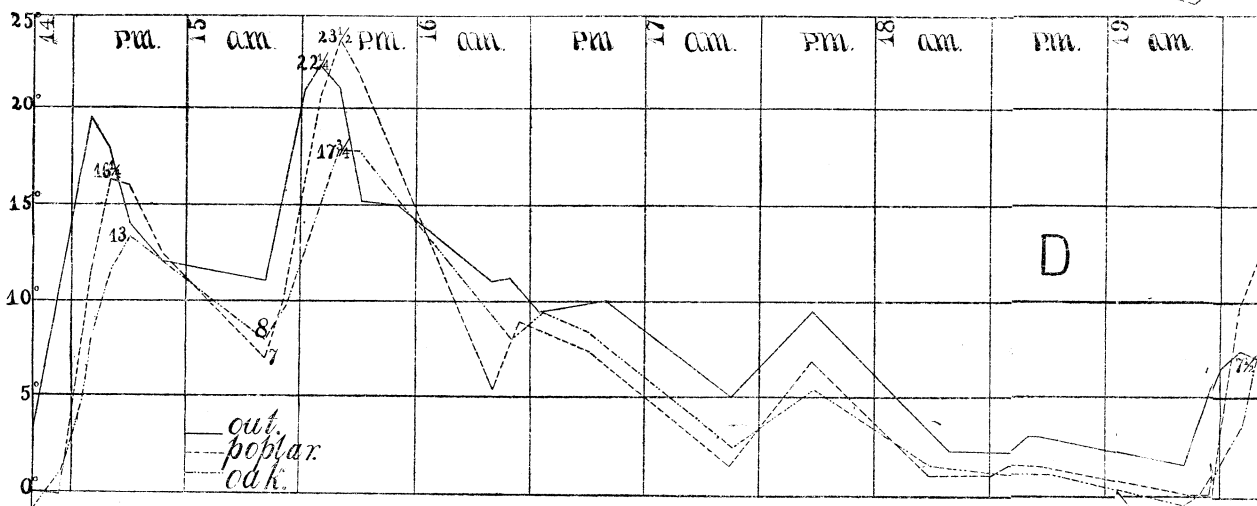
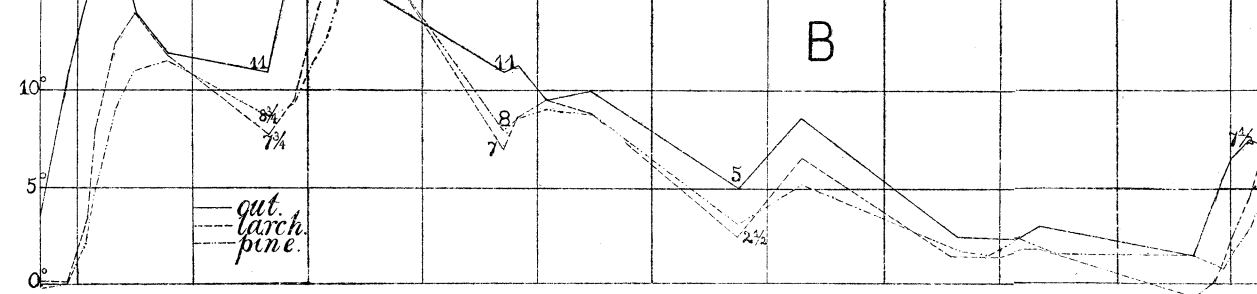
(WITH PLATE XVIII.)

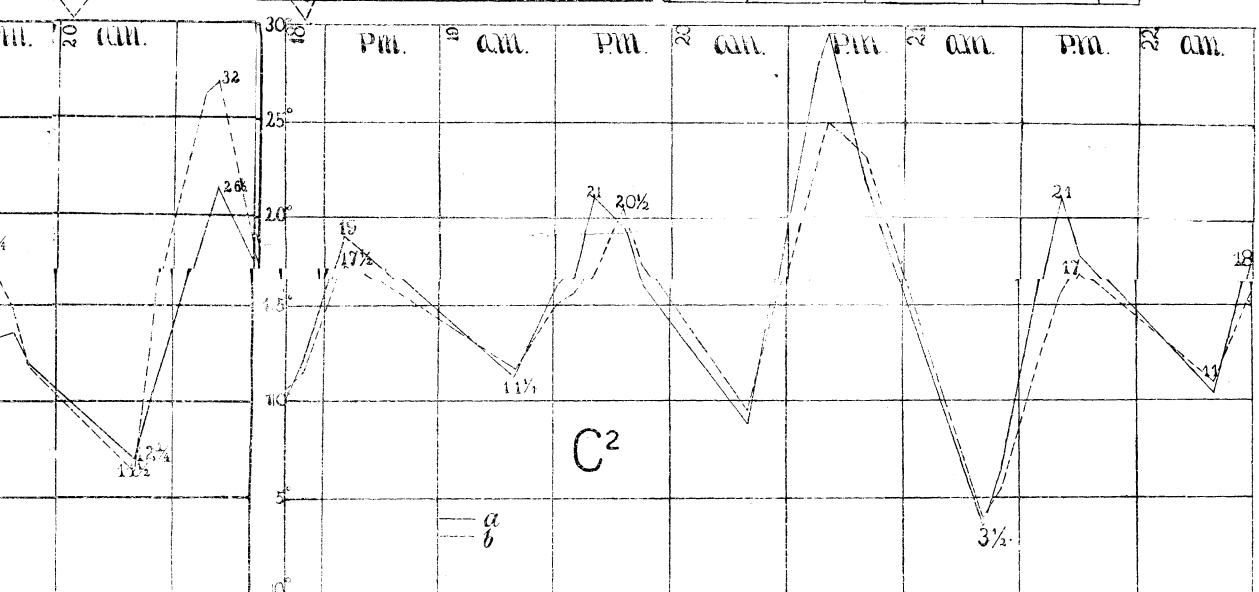
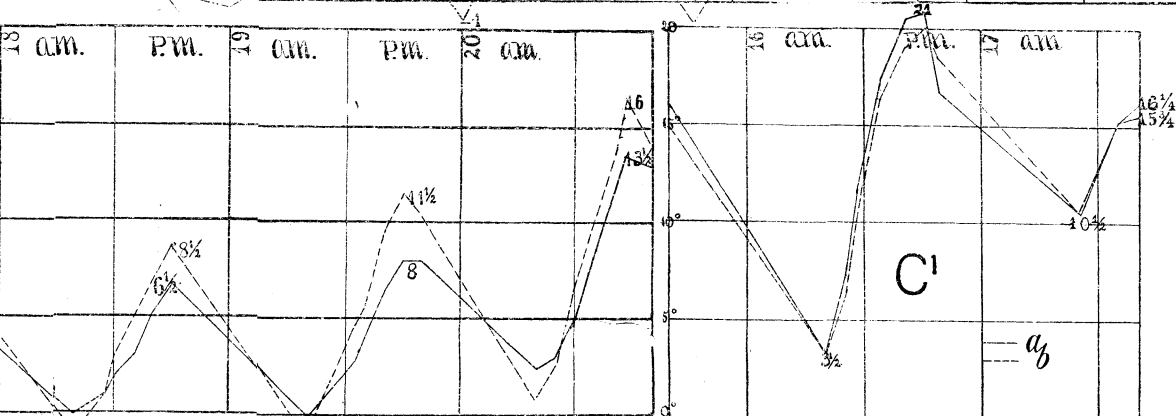
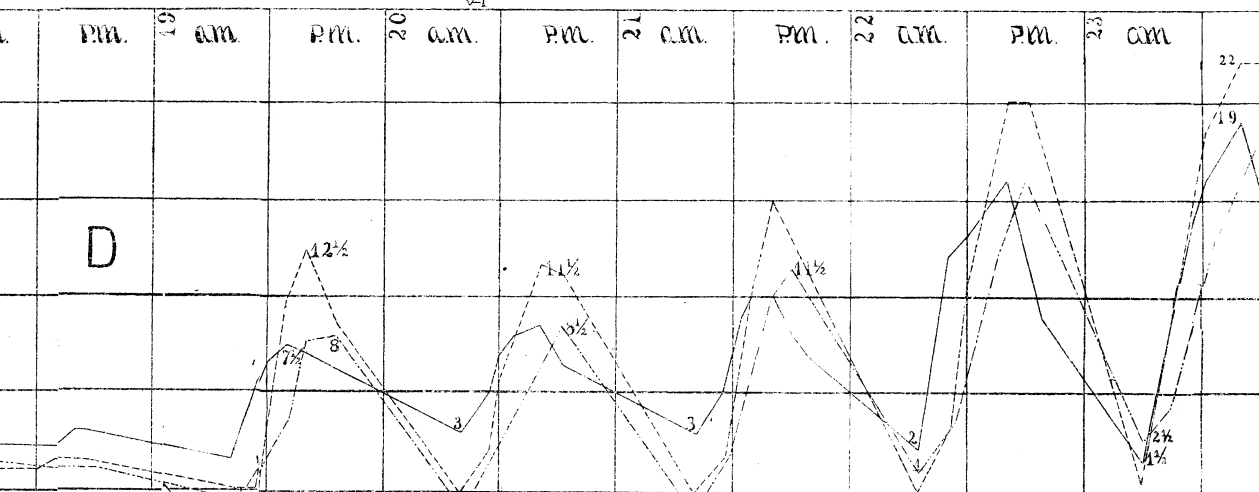
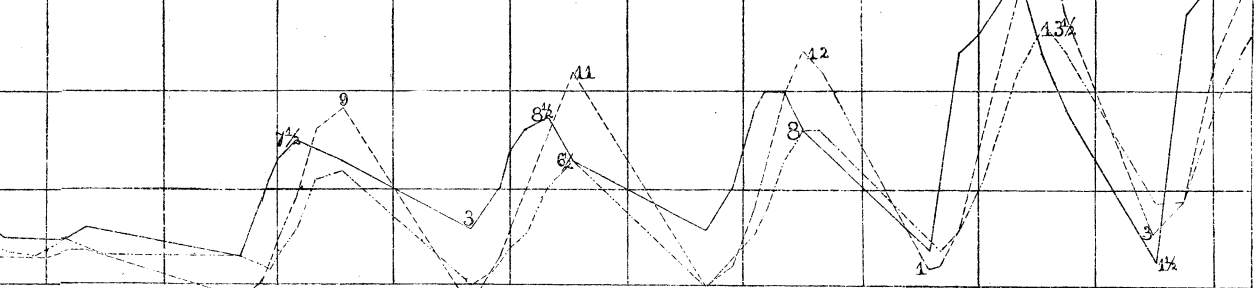
During the winter and spring of 1889 experiments were conducted upon the temperatures of trees, and the following preliminary notice of some of the results obtained is given. A number of questions have arisen in the course of the experiments which will require some time to solve, and as these will have to be postponed till the next winter, it is thought best to lay the facts gained so far before those interested in these problems, and reserve the remainder for further consideration. As far as could be ascertained very few data have been collected upon the subject, and the observations are recorded, as they may possibly be of use in the future.

The experiments were conducted in the following manner: Holes one-half inch in diameter were bored into the trees at equal heights from the ground. The thermometers used were Centigrade, and were carefully compared with each other to detect any variation in graduation. The thermometers were inserted in the borings so that the base of the bulb came in contact with the wood; the space about the thermometer being packed tightly with cotton-wool.









ELL ON TEMPERATURE OF TREES.

An experiment was made upon a good-sized shag-bark hickory (*Carya alba*) to see to what extent the temperature of the interior of the tree followed that of the exterior. The tree was about 30 cm. in diameter, and the borings, which were on the south side, were made at the following depths, viz.: 3, 6, 10, and 12 cm. Readings were taken from the thermometers at these varying depths, and also from one placed on the north side of the tree, not in contact with the bark or exposed to the direct rays of the sun. These readings were noted at intervals of 1 to 2 hours during the day, and in a number of instances were continued through the night. The period of time embraced by the experiment was about fifteen days, and covered several days of warm weather as well as our coldest days.

The detailed readings are not given here, but the results arrived at are essentially as follows. The temperature of the tree as a general rule ranged higher than the outside, with two or three exceptions, when the air temperature was higher during the warmer portions of the day. The maximum temperature of the air was generally between 1 and 2 P. M., while the minimum ranged from 6 A. M. to 7. The following table indicates the average time of the maximum and minimum temperatures for the different depths:

	Maximum.	Minimum.
Outside.	1.00 P. M.	6.45 A. M.
3 cm. deep.	2.00 P. M.	7.00 A. M.
6 cm. deep.	4.15 P. M.	8.00 A. M.
10 cm. deep.	6.15 P. M.	9.30 A. M.
12 cm. deep.	6.45 P. M.	10.00 A. M.

It will be seen by reference to this table that the rate of conduction varies somewhat for different depths; that the heat is both absorbed and radiated more rapidly in the outer layers than in the center.

Representing the temperatures graphically, it was seen that that of the interior of the tree presented the most uniform curve, *i. e.*, one whose amplitude was the least. The mean daily variation for the outside and the shallowest boring was about 12.5° C., while that of the interior was only 7° C. Thus the average temperature of the tree, in its most central part, is not much above the temperature of the air during

the winter months. During the cold days in the early part of February, in which the thermometer fell to -22° C., we find that the interior of the tree registered only 5 degrees higher than this.

To see if there was any material difference between conifers and deciduous trees, an experiment was made with a Scotch pine (*Pinus sylvestris*), and a white oak (*Quercus alba*). The trees selected were of nearly the same diameter, and all other factors were considered, to equalize, as far as possible, the conditions of the experiment. By reference to A, plate xviii, it will be seen that in no case (where conditions were favorable for the experiment) was the temperature of the pine as high as that of the oak, with the exception of the early observations in the day. As a general rule, the observations from 7 to 10 A. M. indicated a higher temperature in the pine than in the oak. This is due to the slower radiation of the pine. It is noticeable that the temperature of the oak falls more rapidly than the pine, late in the afternoon, showing that it radiates the heat absorbed during the warmer portions of the day quicker than the pine, which is clothed with evergreen foliage.

Prof. Prentiss states that conifers have a higher specific heat than deciduous trees in winter.¹ He uses the term specific heat, not in its physical sense, but as meaning the heat evolved by metabolic processes. From the observations made here we have been unable to arrive at similar results. The temperature of the pine we found to be lower than that of the oak at all times except during the latter part of the night and early morning, and the chemical changes occurring in the stem at this season of the year are probably so slight that radiation would carry off the heat about as fast as it was produced. The period of observation for this experiment extended over the middle of March, with the temperature ranging high for this season of the year, but as yet little or no change had taken place in the interior structure of the tree. To see if heat evolved by chemical changes in the tree would be sensible to a thermometer, a comparison was instituted later in April between dead and live timber. The tree selected was a very favorable one for the experiment, inasmuch as it had one large dead branch, with bark intact, while the remaining branch was a vigorous growth. This apple tree was taken for the experiment at a time when the buds were quite well started, so that chemical

¹ 2d Rept. Cornell Univ. Exp. Stat. ('82 and '83), page 42.

action was going on vigorously at the time. The experiment was continued for ten days, but without any very definite results. The maximum of temperature alternated rather irregularly between the live and dead wood, and did not seem to give any uniform results. The causes of these rapid fluctuations are not so easy to understand, yet I think that it is extremely doubtful whether the metabolic processes involved generate sufficient heat to influence the ordinary thermometer.

We have seen above that considerable difference was found between evergreens and deciduous trees like the oak. To see if this same difference was apparent between evergreen and deciduous conifers, an experiment was tried with the pine (*Pinus sylvestris*) and the European larch (*Larix Europæa*). The results obtained are shown in B, plate xviii. They indicate that the temperature of the larch and oak were very nearly the same. As a general rule the temperature of the larch was above the pine during the greater part of the day, the reverse being true for the night and early morning. There is not any very great difference in the structure of the wood of the larch and pine, so that this difference can not be attributable to this cause. It seems to lie in some other direction.

Comparative observations were made with the pine, larch, oak, poplar, and outside air, and in all cases the temperature of the pine was found to be considerably lower than any of the remainder, with the exception mentioned. To what, then, is this lower temperature due? Presumably the thick coating of foliage on the pine exerts a considerable influence upon it, as it would seem to have a tendency to prevent absorption of heat by the trunk, and would very likely interfere with radiation to some extent.

In order to see what influence the foliage had upon the temperature of the trunk, the following experiment was made: Two balsam firs (*Abies balsamea*) were chosen, that were as nearly like each other as possible, and the temperatures of their trunks were compared with each other for a time, to see if any material difference existed between the individual trees. The foliage of this tree presents a compact surface, and was thus better adapted for the experiment than the pine. After a short period of comparison between the two trees, one of them was stripped of its foliage for a distance of several feet above the thermometer, and comparative readings were then taken, to see what influence denudation of foliage exerted upon the temperature of the trunk.

In C^1 , C^2 , Plate xviii, a represents the fir which was later stripped of its branches; b the one that was used for a control experiment. The slight difference between a and b in C^1 may be attributable to the more exposed position of a , and also to the less compact condition of the lower branches. C^2 shows the temperatures of the two trunks after the branches had been removed from a . It will be seen that the greatest variation before stripping was only about 1° C. (see C^1), while there was often a variation of $4-5^\circ$ between them after the branches had been removed from a . It is also noticeable that the temperature of the stripped tree begins to fall more rapidly, and that as a rule it was lower than b in the morning. These results point quite conclusively to the fact that the thick coating of foliage which surrounds the trunk accounts, to a large extent, for the lower temperature of evergreen conifers, and that absorption and radiation go on at a much more rapid rate where trees are not provided with winter foliage.

To see if any material difference existed between the temperatures of woods of different densities, an experiment was first made between a shag-bark hickory (*Carya alba*) and a cultivated crab-apple tree. The hickory was somewhat the larger of the two trees. The specific gravities of the trees show a difference of .1324, the hickory being 0.8372, and the *Pyrus* 0.7048.² The borings were made to a depth of 10 cm., and readings were taken for a period of about ten days, but no very great difference was recorded in the temperatures. It may be noted in this connection that there was no very great difference in the character of the bark, as the bark of the hickory had not begun to exfoliate very much. Another trial was made with a poplar (*Populus grandidentata*) and a white oak (*Quercus alba*). Here the difference in density is much more marked, the specific gravity of the poplar being .4632, while that of the oak is .747, a difference of over 50 per cent.² The borings in this case were not made so deep, in order to see how great a difference existed in the outer layers of the wood proper. The course of these temperatures, as drawn in diagram D, plate xviii, shows that the soft wood was far more variable than the denser wood. Not only was the temperature of the poplars considerably higher during the warm part of the day, but it sank from $1-2^\circ$ below that of the *Quercus* during the night. The range in variation of the poplar averaging about 16.5° C. per day, while

²Report Tenth Census. Sargent: Forest Trees of N. A.

that of the oak was 12.5° . The temperature of the oak remained about the same as the air temperature, while the poplar was often 5° higher during the heat of the day.

The question naturally arises, what causes the difference in temperature between these trees? Does it exist in the different densities of the two woods, or can it be assigned to some other cause? There are several sources to which we might look to find the cause. The different densities of the woods, the heat evolved by chemical changes in the tree, the color and texture of the bark, causing different degrees of absorption, might be suggested as possible causes. It is more than likely that more than one of these possible causes are involved.

If we compare the temperature of the larch and oak, we find that although quite a difference exists between their specific gravities, but little difference is found in their temperatures. The difference in their specific gravities is .1234 or about 20 per cent., while the difference in the mean daily temperature for the length of the experiment does not exceed $\frac{3}{4}^{\circ}$ C. This evidently does not furnish a satisfactory reason for the difference in temperature. The difference in the absorptive powers of different colors is well known, but here I think it plays but a small part. The poplar used for the experiment was covered with a smooth greenish-gray bark, while in the oak the bark was roughened and darker gray in color. The darker the color, the greater the amount of heat absorbed, would lead one to think that the temperature of the oak ought to be higher than the poplar, but such was not the case, so that we must seek still farther for a cause.

Heat due to chemical changes, if sensible to the thermometer, might produce some difference, as the metabolism of the poplar was probably greater at this time than in the oak. But from the experiment conducted upon living and dead timber with the apple tree, it is hardly possible that this would account for the considerable difference that existed between these two trees. The influence of the bark upon absorption plays, I think, a far more important part than either of the above. It was seen that the oak and the larch differed but little in respect to temperature, and here we find quite a similarity in the texture and character of the bark. Both are of a neutral gray tint and are more or less roughened, although scarcely corrugated. To test the influence of the bark upon the temperature, two trees were taken of the same species (*Populus grandidentata*), but with bark of different character.

One of the trees had a close, smooth bark, and the other a thicker, rough, corrugated bark. There was considerable difference in the diameter of the two trees, the smooth one being about 16 cm., and the rough one about 28 cm. in diameter. To eliminate the influence of this difference in volume as much as possible, the borings were made on the south side of the tree to the depth of 6 cm. Reference to diagram E will show the temperatures of the two trees. *a* indicates the rough barked, and *b* the smooth barked poplar. On some days there was a difference of 6 to 10 degrees in the temperatures, the smooth barked tree being the warmer. It was noticeable that on cloudy days, as were the 17th and 18th, that the variation was not so marked. Although the larger volume of *a* would have a tendency to lower its temperature, yet it hardly seems possible that anything like this difference would be caused on this account.

Lack of time at present, prevented further experiments being made upon this point, but the above results point, I think, toward the conclusion, even if they do not warrant us in stating positively that the direct absorption of heat is the main cause of the higher temperature of trees, and that it is largely dependent upon the character of bark.

Botanical Laboratory, Univ. of Wisconsin.

EXPLANATION OF PLATE XVIII.—Vertical scale 1° C.=.1 inch. Horizontal scale, 12 hrs.=.6 inch. A, Showing difference in temperature between evergreen and deciduous trees. B, Showing difference in temperature between evergreen and deciduous conifers. (Period from 16th to 19th indicates continuous rainy weather.) C, Influence of denudation of foliage upon temperature of conifers. C¹, Before stripping off foliage from tree. C², After stripping off foliage from tree; *a*=tree that was stripped; *b*=tree used for control experiment. D, Showing difference in temperature between woods of different densities compared with temperature of the air. E, Showing difference in temperature between two trees of the same species, with bark of different nature.

Paraguay and its flora. I.

THOMAS MORONG.

Land of heat probably most people in the Northern United States would say, if they thought of it at all. True enough, for the mercury in the Fahrenheit thermometer hanging in